How Is Electric Force Related To Charge?A. Inversely Related To ChargeB. Directly Related To ChargeC.

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Understanding the relationship between electric force and electric charge is fundamental to grasping the principles of electromagnetism. Electric force plays a pivotal role in how charged particles interact, and its dependence on charge influences a wide array of phenomena—from the behavior of subatomic particles to the functioning of electrical devices. In this comprehensive article, we will explore the nature of electric force, its relationship with electric charge, and how this relationship manifests in various physical contexts.

What Is Electric Force?

Electric force is the force exerted between charged objects or particles. This force is a fundamental interaction described by Coulomb's Law, which quantifies the magnitude and direction of the force based on the properties of the charges involved and the distance separating them.

Coulomb's Law: The Foundation of Electric Force

Coulomb's Law states that the electric force F between two point charges q_1 and q_2 separated by a distance r is given by:

$$
F = k_e \frac{|q_1 q_2|}{r^2}
$$

where:

- F is the magnitude of the electric force,

- k_e is Coulomb's constant ($8.9875 \times 10^9 \, \mathrm{N\,m^2\,C^{-2}}$),

- q_1 and q_2 are the amounts of the charges,

- r is the distance between the charges.

This law indicates that the electric force:

- Is directly proportional to the product of the magnitudes of the charges,

- Is inversely proportional to the square of the distance between them,

- Acts along the line connecting the two charges,

- Can be attractive or repulsive depending on the signs of the charges.

How Is Electric Force Related To Electric Charge?

The relationship between electric force and electric charge is fundamental and governed by the principles encapsulated in Coulomb's Law. This relationship can be summarized as follows:

Option B: Directly Related To Charge

The most accurate and widely accepted description is that electric force is directly proportional to the magnitude of the charges involved. This means:

- If the magnitude of either charge increases, the electric force increases proportionally,

- If the charges are of opposite signs, the force is attractive; if of the same sign, the force is repulsive.

Mathematically:

$$
F \propto |q_1 q_2|
$$

or explicitly,

$$
F = k_e \frac{|q_1 q_2|}{r^2}
$$

This direct proportionality indicates that larger charges exert stronger forces on each other.

Understanding the Relationship Through Examples

To better understand this proportionality, consider the following scenarios:

- **Increasing charge magnitude:** Suppose two electrons, each with charge $-1.6 \times 10^{-19}\,C$, are separated by a fixed distance. If one electron's charge is increased to $-3.2 \times 10^{-19}\,C$, the electric force between them doubles.

- **Decreasing charge magnitude:** If the charges are reduced to half, the force halves correspondingly.

- **Same charges vs. opposite charges:** The magnitude of the force remains the same, but the direction changes depending on the sign of the charges.

Addressing the Other Option: Inversely Related To Charge

The alternative statement, that electric force is inversely related to charge, is not accurate according to Coulomb's Law. Instead, the inverse relationship applies to the dependence on distance squared, not on the charge itself.

Misconception Clarification

- If someone suggests that increasing charge decreases the electric force, this is incorrect.

- The inverse relationship exists between the electric force and the square of the distance, not the charge.

In summary:

- Electric force increases as charges increase.

- Electric force decreases as the distance between charges increases, specifically inversely proportional to r^2.

The Role of Electric Force in Physics and Everyday Life

The relationship between electric force and charge is not just theoretical; it manifests in numerous practical and natural phenomena.

Electrostatics and Charged Objects

- When you rub a balloon against your hair, electrons transfer, creating charges that repel each other, demonstrating the electric force.

- Static electricity phenomena, such as lightning, occur due to large charges accumulating and exerting immense electric forces.

Electromagnetic Devices

- Electric forces are fundamental to how capacitors store energy.

- Electric motors convert electrical energy into mechanical work based on electromagnetic forces resulting from charge interactions.

Atomic and Subatomic Interactions

- The stability of atoms depends on electrostatic forces between positively charged nuclei and negatively charged electrons.

- Nuclear forces operate at the subatomic level, but Coulomb's Law explains how protons repel each other within the nucleus.

Implications of the Relationship Between Electric Force and Charge

Understanding how electric force varies with charge enhances our ability to predict and manipulate electrical phenomena.

Designing Electronic Components

- Engineers use the proportionality to design circuits, capacitors, and insulators.

Controlling Electric Fields

- Electric fields are created and manipulated based on charge distributions, influencing the electric force experienced by charges within that field.

Safety Considerations

- High charges can produce significant forces, leading to electrical discharges or shocks, which are considered in safety protocols.

Summary: The Key Takeaways

- Electric force is directly proportional to the magnitudes of the charges involved, as per Coulomb's

Law.

- The magnitude of the force increases with larger charges, and decreases with increasing distance.

- The common misconception that electric force is inversely related to charge is incorrect; instead, the inverse square law pertains to the distance.

- Recognizing the proportionality helps in understanding natural phenomena and designing electrical systems.

Conclusion

The relationship between electric force and charge is a cornerstone of electromagnetism. It underscores the significance of charge magnitudes in determining the strength of electrostatic interactions. By understanding that electric force is directly related to charge, scientists and engineers can predict behaviors in atomic structures, electrical devices, and large-scale natural events. This fundamental principle continues to be vital in advancing technology and deepening our understanding of the physical universe.

In summary:

- The correct interpretation is B. Directly Related To Charge.

- Recognizing this relationship allows for better comprehension of both microscopic and macroscopic electrical phenomena.

End of Article

Frequently Asked Questions

What is the relationship between electric force and charge?

The electric force is directly related to charge, meaning it increases as the charge increases.

How does the magnitude of electric force change with charge?

The electric force increases proportionally with the magnitude of the charge, following Coulomb's law.

Is electric force inversely or directly related to charge?

Electric force is directly related to charge, so as charge increases, the force increases.

According to Coulomb's law, what happens to electric force if

the charges double?

The electric force doubles, indicating a direct relationship between charge and force.

Can electric force be inversely related to charge?

No, electric force is not inversely related to charge; it is directly related.

Why does increasing charge lead to a greater electric force?

Because electric force depends directly on the magnitude of the charges involved, so increasing charge results in a stronger force.

Additional Resources

How Is Electric Force Related To Charge?

The relationship between electric force and electric charge is a fundamental concept in physics, underpinning much of our understanding of electromagnetism. As one of the most essential interactions in nature, electric force governs how charged particles interact, influence each other, and give rise to a wide array of phenomena from static electricity to the operation of electronic devices. This article delves deeply into the nature of this relationship, examining whether electric force is inversely or directly related to charge, and exploring the underlying principles, mathematical formulations, and broader implications.

Introduction to Electric Force and Electric Charge

Before exploring their relationship, it is essential to clarify what electric force and electric charge are.

Electric Charge

Electric charge is a fundamental property of matter that causes particles to experience a force when placed in an electric or magnetic field. It exists in discrete units, primarily as positive or negative charges, with the elementary charge (the charge of a proton or electron) approximately equal to 1.602 x 10-19 coulombs. Charges can be:

- Positive: Found in protons.
- Negative: Found in electrons.
- Neutral: When the net charge sums to zero.

Charges can be transferred between objects, leading to phenomena such as static electricity or conductive currents.

Electric Force

Electric force is the electromagnetic force exerted between charged particles. It is one of the four fundamental forces in nature and is characterized by its ability to act at a distance without physical contact. The force can be attractive or repulsive depending on the nature of the charges involved.

The Coulomb's Law: Mathematical Foundation of Electric Force

The primary quantitative description of the electric force between two point charges is given by Coulomb's Law, formulated by Charles-Augustin de Coulomb in 1785.

Statement of Coulomb's Law

Coulomb's Law states that the magnitude of the electric force (F) between two point charges (q1 and q2) separated by a distance (r) in a vacuum is proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance between them:

$$ F = k_e \frac{|q_1 q_2|}{r^2} $$

where:

- F is the magnitude of the force,
- q_1, q_2 are the magnitudes of the charges,
- r is the distance between the charges,
- k_e is Coulomb's constant (~8.9875 x 109 N·m2/C2).

This law reveals two critical relationships:

1. The force is directly proportional to the product of the charges.
2. The force is inversely proportional to the square of the distance.

Is Electric Force Inversely or Directly Related To Charge?

A central question arises: How is electric force related to charge?

To answer this, we analyze the mathematical relationship and the physical implications.

Direct Relationship Between Electric Force and Charge

Based on Coulomb's Law, the electric force has a direct proportionality to the product of the charges involved. If we fix the distance r, then:

- When either or both charges increase in magnitude, the electric force increases proportionally.
- When the charges decrease, the force diminishes proportionally.

Implication: The larger the charges, the stronger the force between them, assuming distance remains constant.

Example:

- Two charges of +1 μC and +1 μC separated by 1 meter produce a force of:

$$
F = k_e \frac{(1 \times 10^{-6}) \times (1 \times 10^{-6})}{1^2} = 8.9875 \times 10^{9} \times 10^{-12} = 8.9875 \times 10^{-3} \text{ N}
$$

- Increasing one charge to +2 μC doubles the force:

$$
F' = 8.9875 \times 10^{9} \times (2 \times 10^{-6}) \times (1 \times 10^{-6}) = 1.7975 \times 10^{-2} \text{ N}
$$

This clear proportionality exemplifies the direct relationship.

Is Electric Force Inversely Related To Charge?

From Coulomb's Law, the inverse relationship appears in the dependence on the square of the distance, not directly on the magnitude of the charges themselves.

However, if we interpret the question in terms of how the force per unit charge behaves, some confusion might arise.

- The force per unit charge on a test charge in an electric field is described by the electric field E, which is proportional to the source charge:

$$
E = k_e \frac{|Q|}{r^2}
$$

- The force F on a test charge q in this field is:

$$
F = qE = q \times k_e \frac{|Q|}{r^2}
$$

\]

Here, the force is directly proportional to the test charge q and the source charge Q.

Understanding the Relationship in Different Contexts

The relationship between electric force and charge can be nuanced depending on the context.

1. Static Point Charges

In the classic Coulomb scenario, the force is directly proportional to both charges involved. Increasing either charge increases the force linearly.

2. Electric Fields and Test Charges

When analyzing how a test charge experiences force in an electric field:

- The electric field E created by a source charge Q is proportional to Q.

- The force $F = qE$ depends on the test charge q.

- The force is directly related to the source charge Q, but the effect on a specific test charge depends on its magnitude.

3. Charge Density and Continuous Charge Distributions

In cases involving continuous charge distributions, the relationship becomes more complex but still fundamentally relies on principles similar to Coulomb's Law, integrating over the distribution.

Physical Implications and Experimental Evidence

The direct relationship between electric force and charge has been confirmed through countless experiments:

- Electroscope tests: Show that increasing the charge on a conductor increases the repulsive force between the leaves.
- Coulomb's experiments: Precisely measured how force varies with charge magnitude.
- Electrostatic force measurements: Demonstrate linearity with respect to charge magnitude.

These experiments reinforce that electric force scales proportionally with charge, consistent with

Coulomb's Law.

Broader Theoretical Contexts

While Coulomb's Law applies to point charges in a vacuum, more advanced theories consider:

- Superposition Principle: The net electric force on a charge is the vector sum of forces due to multiple sources, each proportional to their respective charges.
- Electric field theory: Viewing electric charge as the source of an electric field, which exerts force per unit charge.
- Quantum Electrodynamics (QED): The quantum theory describing electromagnetic interactions, where the force arises from photon exchange, still reflects a proportional relationship to charge.

Conclusion: Synthesis of the Relationship

In summary:

- The electric force is directly related to electric charge, specifically proportional to the product of the involved charges, as articulated by Coulomb's Law.
- The force increases linearly with increasing charge magnitude, illustrating a direct relationship.
- The inverse dependence in Coulomb's Law appears with the square of the distance, not with charge itself.

Therefore, the correct description is:

B. Directly Related To Charge

This fundamental relationship underscores the importance of electric charge in determining the strength and behavior of electrostatic interactions. Understanding this proportionality is crucial for fields ranging from classical electromagnetism to modern electronics and particle physics.

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This comprehensive review emphasizes that electric force is directly related to electric charge, providing both mathematical and conceptual clarity on the topic.

How Is Electric Force Related To Charge A Inversely Related To Chargeb Directly Related To Chargec

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